WASHINGTON STATE DEPARTMENT OF Natural Resources
Doug Sutherland · Commissioner of Public Lands
Division of Geology and Earth Resources
Ron Teissere · State Geologist

Geologic Map of the Washington Portion of the Port Angeles 1:100,000 Quadrangle

by Henry W. Schasse

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INTRODUCTION

This geologic map of the Port Angeles 1:100,000-scale quadrangle covers the north-central slopes and adjacent coastal areas of the Olympic Peninsula and the southern tip of San Juan Island. It was compiled to support the construction of the northwest quadrant of the 1:250,000-scale geologic map of Washington (Dragovich and others, 2002). Until recently, most geologic maps of the peninsula featured bedrock geology. Quaternary deposits were shown primarily where they obscured the bedrock and only as two or three units defined by broad-scope chronological assignment and origin. I have attempted to give equal attention to the Tertiary bedrock and Quaternary sediments in compiling the mapping for the Port Angeles 1:100,000-scale quadrangle.

The Olympia Peninsula bedrock geology shown on this map is largely modified from Tabor and Cady (1978) and Brown and others (1960) with more recent contributions from Schasse and Logan (1998) and Schasse and Wegmann (2000). The bedrock geology for southern San Juan Island is largely modified from Vance (1975), Brandon (1980), and Brandon and others (1988). Additional age dates used to modify the bedrock geology of earlier workers were taken from R. J. Stewart (Univ. of Wash., written commun., 1999), Rau (1998, 2000, 2002), and Brandon and Vance (1992).

The Quaternary geology of the Olympic Peninsula shown on this map is largely modified from Othberg and Palmer (1979a,b, 1982), Othberg and Logan (1977), Washington Department of Ecology (1978), Schasse and Polenz (2002), Schasse and Logan (1998), and Schasse and Wegmann (2000). Quaternary geology west of the city of Port Angeles was subdivided using parent material interpretations derived from a soil survey of the Clallam County area (Halloin, 1987) complemented by field spot-checking and reconnaissance mapping. Landslide deposits in the vicinity of Lakes Crescent and Sutherland are included as presented in Logan and Schuster (1991). Subdivided alpine glacial units and the maximum extent of the late Wisconsinan Cordilleran ice sheet were taken from Long (1975). The surficial geology of southern San Juan Island is taken from Dethier and others (1996). Additional age dates used to characterize the surficial geology of the Port Angeles quadrangle were taken from Dethier and others (1995), Blunt and others (1987), Hallett and others (1997), Heusser (1973), Petersen and others (1983), and Armstrong and others (1965).

Unit symbols used in this compilation generally follow the time–lithology symbology applied by the Washington Division of Geology and Earth Resources in Dragovich and others (2002). The geologic time scale of Palmer and Geissman (1999) was used as the basis for the ages of the bedrock units for this compilation. Provincial biostratigraphic stage correlations are from the "Correlation of Stratigraphic Units of North America" project of the American Association of Petroleum Geologists (Salvador, 1985) and were slightly modified to match parts of the time scale of Palmer and Geissman.

BEDROCK GEOLOGY

The two pre-Tertiary bedrock units exposed on southern San Juan Island are part of a thick and regionally extensive sequence of Late Cretaceous thrust faults and nappes, referred to as the San Juan thrust system of Brandon and others (1988) (see Dragovich and others, 2002, sheet 3, fig. 4). These units are fault-bounded packages of oceanic sediments interbedded with minor volcanic rocks that have been subjected to low-grade metamorphism.

Three major stratigraphic sequences occur within the Tertiary rocks of the Olympic Peninsula:

1. The Eocene to Paleocene Crescent Formation and Blue Mountain unit of Tabor and Cady (1978). The Crescent Formation is interpreted as a marginal rift-basin sequence, while the Blue Mountain unit consists of submarine fan deposits beneath and between the eruptive centers (Wells and others, 1984; Einarsen, 1987; Babcock and others, 1994; Snavely and Wells, 1996).
2. Lower Miocene to Eocene sedimentary and volcanic rocks north of and stratigraphically overlying the Crescent Formation. These include deep-marine rocks of the Aldwell Formation (Brown and others, 1960), marine rocks of the Lyre Formation (Brown and others, 1956, 1960; Tabor and Cady, 1978), marine rocks of the Twin River Group (Brown and Gower, 1958; Snavely and others, 1978), and small exposures of basalt.
3. Oligocene to Eocene sedimentary and minor volcanic rocks tectonically underlying the Crescent Formation including the Needles–Gray Wolf, Elwha, and Western Olympic lithic assemblages of Tabor and Cady (1978). This sequence of deep-marine sedimentary and minor marine volcanogenic rocks represents an exhumed section of the Cascadia accretionary prism (Tabor, 1975).

These stratigraphic sequences are included in two major lithotectonic units that make up the geology of the Olympic Peninsula. The Crescent terrane (Babcock and others, 1994) includes the rocks of the first two stratigraphic sequences listed above and corresponds to the 'peripheral rocks' of Tabor and Cady (1978). These rocks form a horseshoe-shaped outcrop belt surrounding the inboard or east side of the Olympic subduction complex (see Dragovich and others, 2002, sheet 3, fig. 4). The Olympic subduction complex (Brandon and Calderwood, 1990) includes the rocks of the third stratigraphic sequence listed above, and corresponds to the 'core rocks' of Tabor and Cady (1978).

SURFICIAL GEOLOGY

The surficial units exposed in the Port Angeles 1:100,000-scale quadrangle consist primarily of Pleistocene glacial materials deposited by the Juan de Fuca lobe of the Cordilleran ice sheet during the Vashon Stade and Everson Interstade of the Fraser Glaciation. Alpine glacial deposits, formed during the late Wisconsinan, are mapped in the upper valley of the Sol Duc River. Holocene post-glacial sediments were deposited after the ice retreated from the area. Older pre-Fraser glacial and nonglacial deposits exposed primarily in sea cliffs along the Strait of Juan de Fuca and in some north–south drainages are mapped as an all inclusive unit that also contains some post-glacial deposits and deposits of Fraser age.

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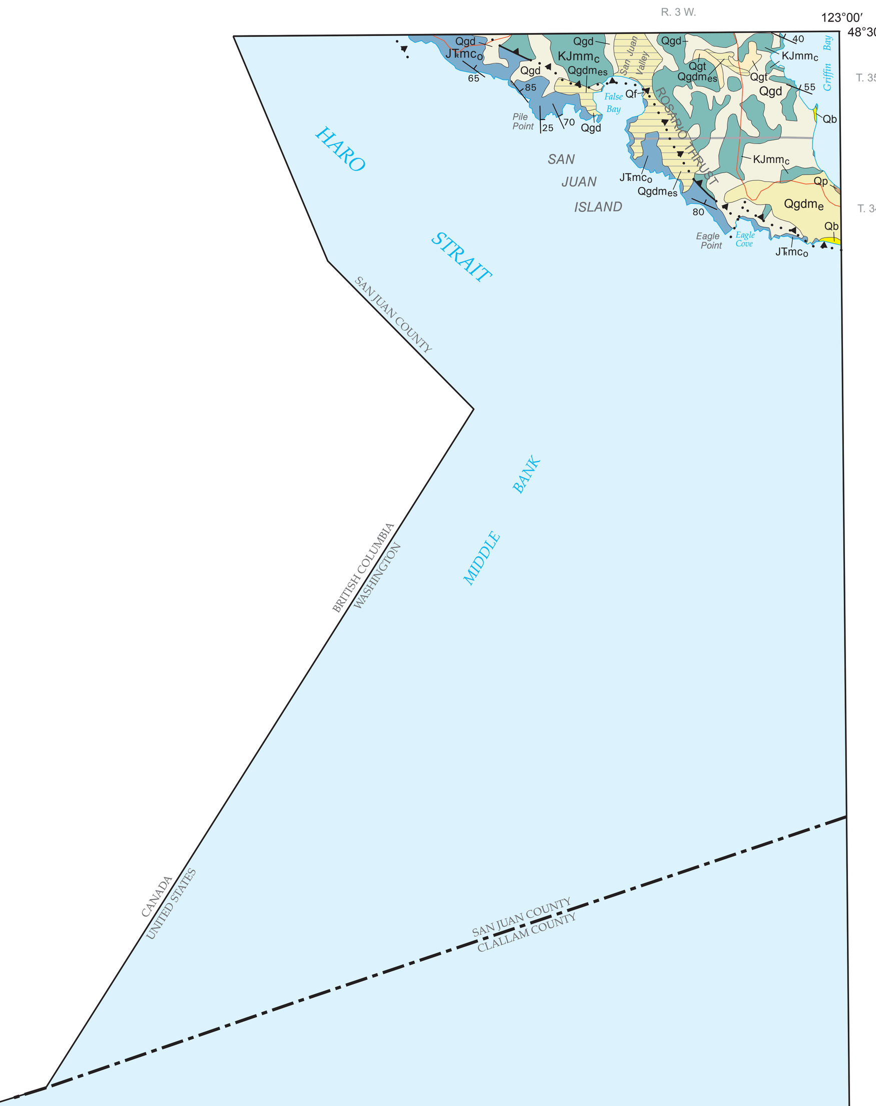
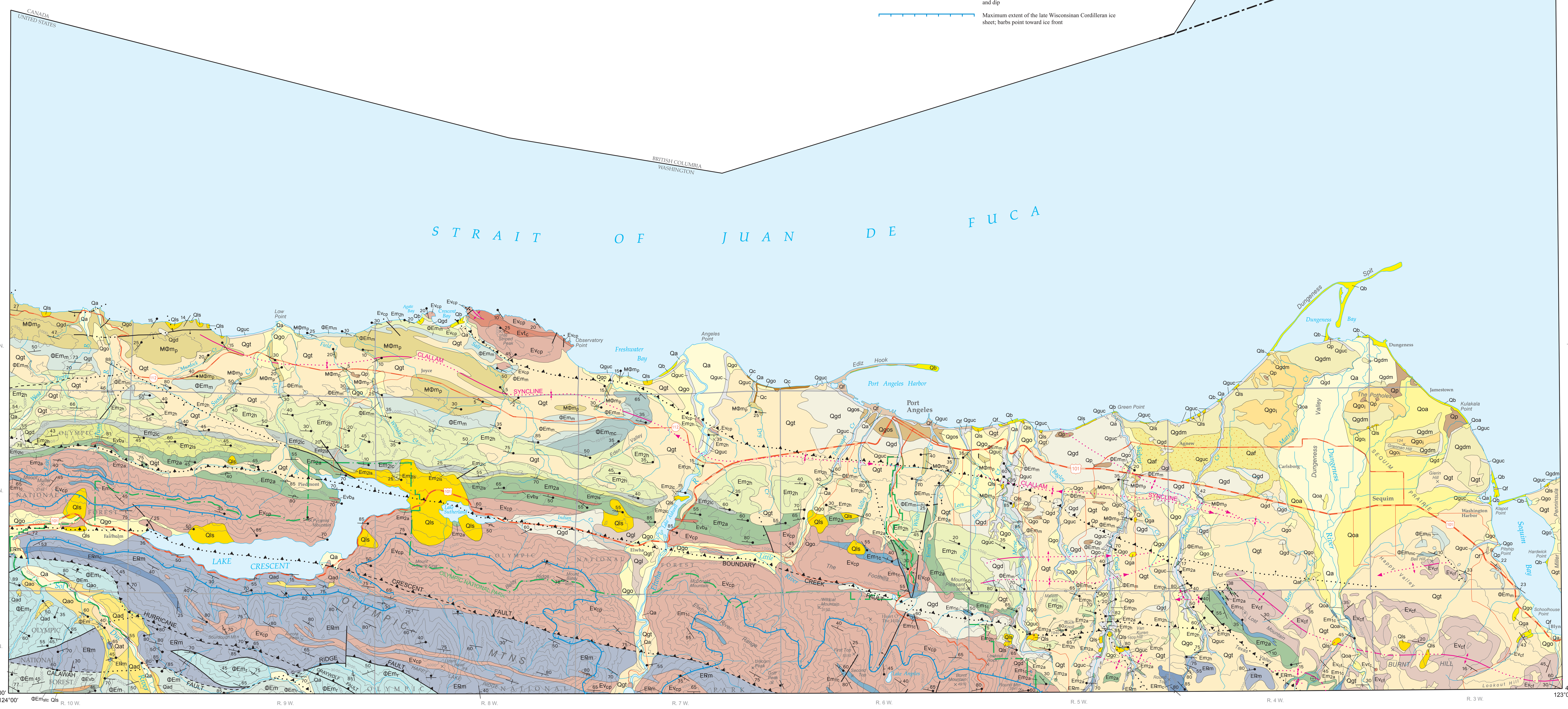
GEOLOGIC SYMBOLS

- Contact
- Contact, scratch boundary
- Fault, unknown offset—dashed where inferred, dotted where concealed
- Fault—bar and ball on downthrown side; dashed where inferred, dotted where concealed
- Thrust fault—sawteeth on upper plate; dashed where inferred, dotted where concealed
- Left-lateral strike-slip fault—dashed where inferred, dotted where concealed
- Anticline—dotted where concealed; large arrowhead shows direction of plunge
- Syncline—dotted where concealed; large arrowhead shows direction of plunge
- Inclined bedding—showing strike and dip
- Inclined bedding—showing strike and dip; top direction of beds known from local features
- Vertical bedding—showing strike
- Vertical bedding—showing strike; ball shows top direction of beds where known from local features
- Horizontal bedding
- Overturned bedding—showing strike and dip
- Inclined bedding in phacoids in shear zone—showing strike and dip
- Inclined bedding in phacoids in shear zone—showing strike and dip. Top direction of beds known from local features
- Inclined deformed foliation—showing approximate strike and dip
- Maximum extent of the late Wisconsinan Cordilleran ice sheet; barbs point toward ice front





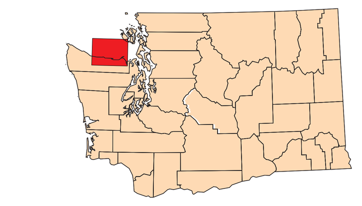
Lambert Conformal Conic Projection
1927 North American Datum
Washington Coordinate System, South Zone
Base map information from the Washington Department of Natural Resources, Geographic Information System, 1997
Washington Division of Geology and Earth Resources
Digital cartography by J. Eric Schuster and Anne C. Heinitz

SCALE 1:100,000

0 1 2 3 4 5 6 7 8 MILES

0 1 2 3 4 5 6 7 8 9 10 KILOMETERS

contour interval 500 feet



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DESCRIPTION OF MAP UNITS

Quaternary Surficial Deposits

NONGLACIAL DEPOSITS

Qf **Artificial fill and modified land (Holocene)**—Riprap, soil, sediment, rock, and solid waste material that has been added and reworked to modify topography; includes engineered and nonengineered fill.

Qb **Beach deposits (Holocene)**—Generally well-sorted sand and cobbles within the influence of the surf zone; may include silt and pebbles; forms elongate spits; larger clasts in coarser deposits are generally well rounded and flat as a result of wave action.

Qa **Alluvium (Holocene)**—Generally well-stratified and well-sorted rounded cobble and pebble gravel, sandy gravel, gravelly sand, silt, and clay; deposited in and along present streams; grain size varies both laterally and vertically due to stream migration.

Qp **Peat and marsh deposits (Holocene)**—Peat, muck, and lacustrine silt and clay rich in organic matter; formed by the accumulation and decomposition of organic material in wet depressions and other areas of poor drainage.

Qls **Landslide deposits (Holocene and Pleistocene?)**—Clay, silt, sand, gravel, and larger blocks deposited by mass wasting; may be unstratified, broken, chaotic, and poorly sorted or may retain primary bedding, depending on degree of activity, location within the slide mass, type of slide, cohesiveness, and competence of materials; commonly hummocky; mostly earth-slump blocks resulting from streams or wave action undercutting the toes of these blocks along steep stream-valley walls and shoreline bluffs.

Qoa **Older alluvium (Holocene and late Pleistocene?)**—Stratified gravel, cobbles, sand, and silt in terraces above modern flood plains; commonly iron-oxide stained; exposures are axial-channel and flood-plain terrace deposits of an ancestral Dungeness River (Schasse and Wegmann, 2000; Schasse and Logan, 1998; Othberg and Palmer, 1979a, 1982). A tephra from this unit has been identified as Mazama ash, dated elsewhere at 6,730 ±40 ^{14}C yr B.P. (Hallet and others, 1997), establishing a minimum age; the lower part of this unit may be as old as late Pleistocene (Schasse and Wegmann, 2000).

Qaf **Alluvial fan deposits (Holocene and Pleistocene?)**—Thin- to medium-bedded sand and interbedded silt and clayey silt, with lenses of sand and pebbly gravel; sands are gray to yellowish brown, fine to medium grained, and well sorted; fan surfaces grade to surface of Vashon glaciomarine drift (unit Qgdm) in the vicinity of McDonald Creek west of Sequim. A tephra from the upper part of this unit was correlated with the Mazama ash dated at 6,730 ±40 ^{14}C yr B.P. (see Schasse and Wegmann, 2000). Othberg and Palmer (1982) suggested that the lower part of the unit may interfinger with glaciomarine drift (unit Qgdm) deposited during the late Pleistocene.

Qc **Continental sediments (Pleistocene)**—Pre-Fraser fluvial, iron-oxide-stained, partially cemented pebble to cobble gravel; contains lenses of iron-oxide-stained sand. Clasts are predominantly basalt and sandstone from the Olympic Mountains; probably deposited by an ancestral Elwha River as a delta into the Strait of Juan de Fuca.

CONTINENTAL GLACIAL DEPOSITS, FRASER GLACIATION

Qgdm **Glaciomarine drift (Pleistocene)**—Poorly sorted, weakly stratified to non-stratified, poorly compacted pebbly silt and clay with discontinuous layers of silty sand; weathers to a pseudo-columnar appearance on vertical sea-cliff faces; tan to gray, weathers to dark to pale yellowish brown; rare marine fossils. A shell from the unit collected northwest of Sequim yielded a ^{14}C age of 12,600 ±200 yr B.P. (Dethier and others, 1995), indicating that unit Qgdm was deposited during the time interval established for the Everson Interstade of the Fraser Glaciation; however, it is not clear that the label 'Everson' should be applied to deposits this far west of the Puget Lowland.

Qgdm$_{es}$ **Glaciomarine drift, subtidal deposits, Everson age (Pleistocene)**—Moderately to well-sorted sand, silty sand, and silt containing local pods and lenses of gravel; laminated to thin bedded, locally massive or cross stratified; gray to bluish gray; generally overlies marine diamicton, till, and undifferentiated diamicton (units Qgdm$_e$, Qgt, and Qgd); preserved in topographic depressions below 200 ft elevation; locally fossiliferous; deposited in a glaciomarine or marine environment during the Everson Interstade. Radiocarbon ages from shells range from about 12.9 to 12.5 ka. (Description and ages compiled from Dethier and others, 1996.)

Qgdm$_e$ **Glaciomarine drift, marine diamicton, Everson age (Pleistocene)**—Poorly to moderately sorted pebbly silt and diamicton; contains lenses and discontinuous beds of silt, sand, and gravel; massive to poorly stratified; unweathered matrix is light olive-gray to gray, locally bluish gray; sparsely to highly fossiliferous; overlies Vashon till (unit Qgt); generally underlies marine subtidal deposits (unit Qgdm$_{es}$); locally mantles the landscape below 200 ft elevation; deposited in a glaciomarine or marine environment during the Everson Interstade; radiocarbon ages from shells range from about 13.1 to 12.8 ka. (Description and ages compiled from Dethier and others, 1996.)

Qgos **Vashon recessional outwash sand (Pleistocene)**—Proglacial sand, pebbly sand, and interbedded silt; thin to medium bedded; fine to medium grained; well sorted; light gray to pale yellowish brown; low-energy fluvial sand deposits occur in the Port Angeles area adjacent to stream valleys draining the Olympic Mountains; may correlate with the lower parts of alluvial fan deposits (unit Qaf) west of Sequim. Coastal geology (Washington Department of Ecology, 1978) suggests that these deposits may have been deposited in a deltaic environment during a period of higher sea level during the late Pleistocene.

Qgo$_i$ **Vashon recessional ice-contact outwash (Pleistocene)**—Moderately sorted, crudely to well-stratified pebble to cobble gravel and sand; thin to thick bedded; locally grades to sand; pale yellowish brown to gray; shows deformation, slumping, and collapse features resulting from the melting of supporting ice; expressed geomorphically as kettled topography, eskers, and kame terraces; stratified gravels locally interfinger with and are overlain by glaciomarine drift (unit Qgdm), suggesting that the gravels were deposited near the margin of grounded stagnant melting ice in a coastal marine environment (Othberg and Palmer, 1979a,b, 1982).

Qgo **Vashon recessional outwash (Pleistocene)**—Chiefly proglacial, stratified, moderately to well-rounded, poorly to moderately sorted outwash sand and gravel; locally contains silt and clay; also contains lacustrine deposits and ice-contact stratified drift; lies stratigraphically above till (unit Qgt). Age is constrained between the time of recession of the Juan de Fuca lobe from its terminal zone, established by a ^{14}C date of 14,460 ±200 yr B.P. near the western margin of the Strait of Juan de Fuca (Heusser, 1973), and a ^{14}C date of 12,300 ±310 yr B.P. from wood collected from sediments 1 in. above Vashon till (unit Qgt) at the Manis Mastodon site southwest of Sequim (Petersen and others, 1983).

Qgt **Vashon till (Pleistocene)**—Most commonly lodgment till consisting of an unstratified, highly compacted mixture of poorly sorted clay, silt, sand, gravel, and boulders deposited directly by glacier; gray where fresh and yellowish gray to light gray and tan where oxidized; locally includes ablation till of varied thickness and characterized by irregular hummocky topography. Lies stratigraphically between overlying recessional outwash (unit Qgo) and underlying advance outwash (unit Qga); age is bracketed by ^{14}C ages from Vashon advance outwash near Sequim of about 17.5 to 18.5 ka (Blunt and others, 1987) and a ^{14}C date of about 14.5 ka from a bog on Vashon Drift near the western margin of the Strait of Juan de Fuca (Heusser, 1973). On southern San Juan Island, consists of a poorly sorted, compact mixture of silt, sand, and clay containing pebble to boulder gravel; generally nonstratified, but locally contains subhorizontal layering, parting, and deformation structures; locally contains lenses, pods, and thin discontinuous beds predominantly of sorted gravel; olive-gray and gray where unoxidized and olive to buff where oxidized; generally rests on striated bedrock and underlies marine diamicton (unit Qgdm$_e$). Age is older than 13.2 ka. (Description and ages for unit on San Juan Island compiled from Dethier and others, 1996.)

Qga **Vashon advance outwash (Pleistocene)**—Sand, gravel, and lacustrine clay, silt, and sand deposited during glacial advance; gray where fresh, grayish brown and grayish orange where weathered; sands commonly thick, well sorted, and fine grained; mapped where its stratigraphic position beneath Vashon till (unit Qgt) can be established. In sea-cliff exposures between Siebert and Morse Creeks, displays prominent west-dipping foreset beds with very large angular silt rip-up blocks (5 ft or greater) resembling underlying nonglacial silts; foreset beds are laterally continuous over a distance of about 2.5 mi and are interpreted to represent one or more glacial outburst flood events during glacial advance (Schasse and Polenz, 2002). Age in the Port Angeles 1:100,000-scale quadrangle is between 17.5 and 18.5 ka as reported by Blunt and others (1987) from bluff exposures west of Sequim.

Qgl **Vashon glaciolacustrine deposits (Pleistocene)**—Sand, silt, and clay deposited in proglacial lakes; laminated, with disseminated dropstones; medium gray where wet and fresh, tan where dry and oxidized; formed during both glacial advance and recession.

Qgd **Vashon Drift, undivided (Pleistocene)**—Glacial deposits of Vashon age consisting of mixtures of sand and gravel, lodgment till, sandy ablation(?) till, and lacustrine(?) silts; commonly characterized by hummocky topography. Represents those materials not separately mappable as units Qgo, Qgl, Qgt, or Qga at the map scale; age range is that of the included units (~12–19 ka). On southern San Juan Island, consists of poorly sorted, generally nonstratified till covered by 1.5 to 10 ft of marine diamicton (unit Qgdm$_e$); mapped below 200 ft elevation where till (unit Qgt) and marine diamicton (unit Qgdm$_e$) cannot be differentiated at map scale; generally unfossiliferous. (Description of unit on San Juan Island compiled from Dethier and others, 1996.)

GLACIAL AND NONGLACIAL DEPOSITS OF FRASER AND PRE-FRASER AGE

Qguc **Undifferentiated surficial deposits (Holocene–Pleistocene)**—Clay, silt, sand, gravel, till, diamicton, and peat; shown where steep slopes preclude more detailed delineation at map scale; includes pre-Holocene deposits and Holocene alluvium or landslide deposits found along steep slopes of narrow stream valleys; also includes poorly exposed sediments at the base of the Vashon Drift whose stratigraphic assignment is undetermined; includes part of the Double Bluff, Possession, and Everson Glaciomarine Drifts, part of the Vashon Drift undivided, part of the Whidbey Formation, and part of the Olympia-age nonglacial beds (Armstrong and others, 1965).

ALPINE GLACIAL DEPOSITS, LATE WISCONSINAN AGE

Qao **Alpine outwash (Pleistocene)**—Stratified sand, gravel, silt, and clay; characterized by clasts derived from the Olympic Mountains; gray where unweathered, weathers to grayish orange to yellow brown; includes high river terraces that may not be directly associated with glaciation (Tabor and Cady, 1978; Long, 1975).

Qat **Alpine till (Pleistocene)**—Lodgment till; very compact and unsorted, containing rounded to subangular clasts in a clay–silt matrix; clasts are derived from the Olympic Mountains and range in size from pebbles to boulders; blue-gray where unweathered, oxidized to deep orange-brown; contains numerous well-striated and polished clasts (Long, 1975).

Qad **Alpine drift, undifferentiated (Pleistocene)**—May include till, outwash, morainal deposits, and other sediments from local upland sources.

Tertiary Sedimentary and Volcanic Rocks

ROCKS OF THE CRESCENT TERRANE OF BABCOCK AND OTHERS (1994)

Twin River Group—Divided into:

ΜΦm$_p$ **Pysht Formation (Miocene–Oligocene)**—Massive, poorly indurated marine mudstone, claystone, and sandy siltstone; also contains beds of very thick calcareous sandstone (1–20 ft thick). Unweathered mudstone, claystone, and siltstone are medium gray to dark greenish gray, pale yellowish brown where weathered. Mudstone locally contains thin beds of calcareous claystone; argillaceous rocks commonly contain sparsely disseminated calcareous concretions that are spherical, cylindrical, or irregular in shape. Mollusk shell fragments, foraminifera, and carbonized plant material are common in mudstone. Gradational with the underlying Makah Formation (unit ΦEm$_m$)(Snavely and others, 1978). Contains Saucesian and upper Zemorrian foraminifera (Rau, 1964, 1981, 2000, 2002); mollusks are indicative of the Juanian Stage (Addicott, 1976, 1981). (Description compiled from Brown and others, 1960; Schasse and Wegmann, 2000.)

ΦEm$_m$ **Makah Formation (Oligocene–Eocene)**—Massive to locally thin- and rhythmically bedded siltstone and mudstone and minor thin-bedded sandstone; generally greenish gray to olive-brown, weathers to grayish orange and yellowish brown; locally dark gray to black where carbonaceous; spherical calcareous concretions (often containing fossil shells and plants) and nodules occur throughout. Sandstone is very fine to medium grained, subquartzose, and feldspatholithic, and is most common in the eastern part of the map area. Gradational with the underlying Hoko River Formation (unit Em$_{2h}$)(Snavely and others, 1978). Contains upper Narizian and Refugian foraminifera (Rau, 1964, 2000, 2002). (Description compiled from Brown and others, 1960; Schasse and Logan, 1998.) Locally divided into:

ΦEm$_{mc}$ **Conglomerate and granule sandstone**—Massive pebble–cobble conglomerate and granule sandstone cropping out at the base of unit ΦEm$_m$ 2 mi west of the Elwha River. Conglomerate is composed of pebbles and cobbles of varied lithology (similar to the Lyre Formation, unit Em$_{2lc}$) in a matrix of coarse-grained to granule sandstone. A sedimentary breccia composed almost entirely of angular volcanic debris is sporadically exposed at the base of the conglomerate (Brown and others, 1960). Subquartzose, feldspatholithic, medium- to thick-bedded, medium-grained to granule sandstone that grades to small-pebble conglomerate crops out at the base of unit ΦEm$_m$ on Bell Hill south of Sequim; rounded pebble clasts consist of basaltic material eroded from the Crescent Formation (unit Ev$_{cf}$). Contains marine pelecypod and brachiopod macrofossils and oyster shell fragments (Schasse and Logan, 1998); also contains Refugian foraminifera (Rau, 1998).

Em$_{2h}$ **Hoko River Formation (upper Eocene)**—Sandstone and siltstone with pebble–cobble conglomerate lenses; consists of equal amounts of sandstone and siltstone that intergrade laterally and vertically; beds of pebble–cobble conglomerate occur locally near the base. Sandstone is lithofeldspathic, well bedded, thin to medium bedded and locally very thick bedded, fine to medium grained and locally very coarse grained to granular, and gray to olive-gray; siltstone is well bedded, well indurated, locally cemented with calcium carbonate, and contains thin beds and laminae of very fine-grained sandstone; calcareous concretions occur locally. Rests conformably on the underlying Lyre Formation (units Em$_{2lc}$ and Em$_{2ls}$). Contains upper Narizian foraminifera (W. W. Rau in Snavely and others, 1980; Schasse and Wegmann, 2000). (Descriptions compiled from Brown and others, 1960; Schasse and Wegmann, 2000.)

Em$_{2lc}$ **Em$_{2ls}$** **Lyre Formation (middle Eocene)**—Conglomerate and sandstone (unit Em$_{2lc}$) overlying and interbedded with sandstone and minor thin-bedded sandstone and siltstone (unit Em$_{2ls}$). Conglomerate is subdivided into lenticular or channel deposits of thin- to very thick-bedded, well-rounded pebble to boulder conglomerate and pebbly sandstone; clasts are dark gray to black argillite, quartzite, chert, metavolcanic rocks, gneiss, quartz, and minor basalt; also contains lenses of fine-grained to granule sandstone. Sandstone is light olive-gray, thick bedded, well indurated, lithic, phyllitic, and quartzose; large siltstone rip-ups and pebbly mudstone are common near lower contact. Rests conformably upon and interfingers with the upper part of the Aldwell Formation (unit Em$_{2a}$). Contains foraminifera assigned to the upper Narizian Stage by W. W. Rau (in Snavely, 1983).

Em$_{2a}$ **Aldwell Formation (middle Eocene)**—Thin- to medium-bedded, well-indurated marine siltstone and sandy siltstone with sparse interbeds of fine- to very fine-grained feldspatholithic sandstone. Siltstone contains thin sandy laminations and local thin to medium beds of fine-grained limestone or limy very fine-grained sandstone. Siltstone is olive-gray to gray and black; sandstone is greenish gray and weathers to brown and olive-gray; limy beds are distinguished by their tan weathered surfaces. Massive lenses of unsorted pebbles, cobbles, and boulders of basalt occur sporadically throughout the siltstone; pillow lava, lenses of basalt breccia, and water-laid lapilli tuff (similar to units Ev$_{cp}$ and Ev$_{cf}$ of the underlying Crescent Formation) occur locally near the base. Characterized by lower Narizian foraminifera, indicating a middle Eocene age (Armentrout and others, 1983; Rau, 1964). Rau (2000) identified foraminifera representative of the lower Narizian and Ulatisian Stages. Locally divided into:

Evb$_a$ **Basaltic rocks**—Pillow basalt, breccia, and tuff similar to the Crescent Formation (unit Ev$_{cp}$); consists of mappable tongues up to 350 ft thick and occurring up to 1000 ft above the base of unit Em$_{2a}$ (Brown and others, 1960).

Crescent Formation (middle and lower Eocene)—Divided into:

Ev$_{cf}$ **Marine basaltic rocks, flow dominated**—Tholeiitic basalt, basalt breccia, volcaniclastic conglomerate, and tuff; minor diabase and gabbro sills and dikes; subordinate pillow basalt and rare rhyolite; minor interbeds of marine siltstone, feldspatholithic and basaltic sandstone, chert, and gray foraminiferal limestone; mostly aphyric; dark gray and dark greenish gray, weathering to brown and dark brown. Flows are characterized by closely spaced joints, sometimes radially oriented; breccia consists of angular clasts of basalt, typically 2 to 4 in. in diameter. Contains foraminiferal assemblages referable to the Ulatisian Stage (Rau, 1981); Babcock and others (1994) give an $^{40}Ar/^{39}Ar$ plateau age of 50.5 Ma near the top of a correlative unit outside the map area. Consists of the upper part of the Crescent Formation.

Ev$_{cp}$ **Marine basaltic rocks, pillow dominated**—Tholeiitic pillow basalt, basalt breccia, and volcaniclastic sandstone and conglomerate; includes minor aphyric basalt flows, minor gabbroic dikes and sills, and rare rhyolite; locally contains thin interbeds of basaltic tuff, chert, red argillite, limestone, and siltstone; contains abundant chlorite and zeolites. Reported $^{40}Ar/^{39}Ar$ plateau ages are 45.4 to 52.9 Ma within the map area and as old as 56.0 Ma outside the map area (Babcock and others, 1994); contains foraminiferal assemblages referable to the Penutian to Ulatisian Stages (Rau, 1964). Age discrepancies between this and overlying unit Ev$_{cf}$ suggest that basalts may be part of separate extrusive centers (Babcock and others, 1994). Consists of the lower part of the Crescent Formation.

Evt$_c$ **Tuffaceous rocks**—Water-laid tuff, mudflow breccia, and tuffaceous sedimentary rock. Tuff consists of light greenish gray dacite, rhyolite, and andesite (Brown and others, 1960; Tabor and Cady, 1978); shows local evidence of metamorphism where it contains garnet porphyroblasts and mineral assemblages indicative of the greenschist and epidote–amphibolite metamorphic facies (Brown and others, 1960).

Evr$_c$ **Rhyolite**—Porphyritic rhyolite; consists of milky-white plagioclase phenocrysts in light gray and pale pink aphanitic groundmass. Altered spherulites suggest rhyolite extruded as lava flows (Schasse and Logan, 1998). Occurs east of the Dungeness River on Burnt Hill.

Em$_{1c}$ **Marine sedimentary rocks**—Breccia, conglomerate, volcanolithic sandstone, argillite, limestone, and chert; green, red, or black; clasts chiefly basalt and diabase; micaceous, carbonaceous, lithic, calcareous, and fossiliferous. Interfingers with basaltic rocks (units Ev$_{cp}$ and Ev$_{cf}$); at Lost Mountain. Contains Ulatisian or older foraminifera (Rau, 2000).

Blue Mountain unit of Tabor and Cady (1978) (Eocene–Paleocene?)—Divided into:

EPm **Marine sedimentary rocks**—Gray to black lithic sandstone, siltstone, argillite, granule or pebble conglomerate, and siltstone- or slate-clast breccia; commonly laminated and rhythmically bedded; locally contains very thick sandstone beds. Contains foraminiferal assemblages referable to Ulatisian or older stages (Rau, 2000); Babcock and others (1994) report $^{40}Ar/^{39}Ar$ ages of 45.4 to 56.0 Ma from overlying Crescent Formation volcanic rocks.

EPm$_c$ **Conglomerate and pebbly sandstone**—Thick-bedded to massive conglomerate and pebbly sandstone with minor interbedded argillite; contains greenish gray subrounded pebbles and minor cobbles of dark-gray chert and volcanic rocks with less-abundant light-gray sandstone and rare calcareous concretions; abundant very dark gray to grayish-black angular siltstone rip-up clasts locally form slate-chip breccia. Interbedded with rocks of Eocene to Paleocene age (unit EPm); believed to be a submarine channel facies of unit EPm (Einarsen, 1987).

ROCKS OF THE OLYMPIC SUBDUCTION COMPLEX OF BRANDON AND CALDERWOOD (1990)

ΦEm **Marine sedimentary rocks (Oligocene–Eocene)**—Sandstone and minor granule conglomerate with generally less than 40 percent siltstone and argillite; sandstone and siltstone are feldspatholithic and lithofeldspathic, bluish gray to black weathering to brown, medium to very thick bedded, angular, poorly sorted, commonly micaceous, and locally calcareous; commonly contains graded beds with quartz and chert granule conglomerates, sole structures, and cross-bedding; sedimentary breccias, thin coaly laminae, and carbonaceous debris are common; argillite is gray to black, commonly with fine-grained sandstone in rhythmic sequences; commonly sheared in the vicinity of the Calawah fault. Contiguous with rocks to the west yielding detrital zircon fission-track minimum ages ranging from Oligocene to Eocene (R. J. Stewart, Univ. of Wash., written commun., 1999). Consists of part of the Western Olympic lithic assemblage of Tabor and Cady (1978).

ΦEm$_r$ **Marine rhythmites and other thin-bedded sedimentary rocks (Oligocene–Eocene)**—Laminated and (or) thin-bedded (0.5–8 in.), lithofeldspathic and feldspatholithic, micaceous sandstone, siltstone, slate, and argillite; rare thick-bedded sandstone, granule conglomerate, and thick-layered (>24 in.) semischist, all containing platy slate clasts grading to platy-clast breccia; metamorphosed to zeolite facies; argillite locally contains black coarse-grained limestone lenses and concretions; slate locally occurs with phyllite; tectonic lenses are common. Contiguous with rocks yielding detrital zircon fission-track minimum ages ranging from Oligocene to Eocene (Brandon and Vance, 1992; R. J. Stewart, Univ. of Wash., written commun., 1999). In the Mount Olympus 1:100,000-scale quadrangle to the south (Gerstel and Lingley, 2003), contains megafossil assemblages referable to the Tejon Stage (Squires and Geodert, 1997). Consists of part of the Needles–Gray Wolf, Western Olympic, and Elwha lithic assemblages of Tabor and Cady (1978).

ΦEm$_{stc}$ **Marine pebble conglomerate (Oligocene–Eocene)**—Generally very thick-bedded marine pebble conglomerate; contains well-rounded pebbles (≤2 in.) of chert, quartzite, volcanic rocks, limestone, and sandstone; metamorphosed to zeolite facies; interbedded with Oligocene to Eocene marine rocks (unit ΦEm); consists of part of the Western Olympic lithic assemblage of Tabor and Cady (1978).

ΦEvb **Basalt (Oligocene–Eocene)**—Basalt, greenstone, and greenschist; includes argillite and limestone; interbedded with Oligocene to Eocene rocks (unit ΦEm). (Description compiled from Tabor and Cady, 1978.)

Pre-Tertiary Marine Metasedimentary Rocks

KJmm$_c$ **Constitution Formation (Cretataceous–Jurassic)**—Poorly to moderately sorted volcaniclastic sandstone, cherty sandstone, mudstone, and conglomerate with less-abundant ribbon chert, green tuff, and basalt and dacite pillows; includes rare limestone. Clastic rock types are commonly massive and locally graded; sandstone is commonly turbiditic; mudstone is commonly massive. Conglomerate contains rounded to angular volcanic, chert, metaplutonic, and schistose clasts in a siltstone matrix; rhythmically bedded ribbon chert is commonly interbedded with clastic rocks throughout the unit but more abundant near the base. Green tuff occurs near base of section and is commonly fine grained and indurated; pillow lava is interlayered with clastic rocks; limestone occurs near base of unit as isolated pods. Metamorphic minerals in clastic rocks include albite, quartz, chlorite, calcite/aragonite, and white mica ± lawsonite and (or) prehnite (Brandon, 1980; Brandon and others, 1988). Structurally overlies unit JŦmc$_o$. Age is poorly constrained, but radiolarians from chert give Early Cretaceous or Late Jurassic ages (Brandon and others, 1988).

JŦmc$_o$ **Orcas Formation (Jurassic–Triassic)**—Ribbon chert with less-abundant pillow basalt, mafic tuff, limestone, and mudstone; intraformational chert breccia and coarse chert-lithic sandstone occur locally; bedding commonly contorted where preserved; ribbon chert is well bedded with shaly interbeds; pillow basalt and mafic tuff are interbedded with chert; limestone is recrystallized into aragonite marble (Vance, 1968) and occurs as interbeds in chert and as olistolithic blocks; interbedded mudstone and mafic tuff are locally abundant. Early Jurassic to Triassic ages were determined from radiolarians in chert, and limestone associated with chert yields Late Triassic conodonts (Brandon and others, 1988). Consists of part of the Deadman Bay terrane of Brandon and others (1988).

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